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Preliminary Aerial Photo Stand-Volume Tables for Some California Timber Types

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ABSTRACT: Presents board-foot and cubic-foot photo stand volume tables for white wood timber types(ponderosa pine, Jeffrey pine, white fir, red fir,Douglas-fir) and old-growth redwood. Tables are intended for use in two-stage stratified sampling designs.

As the demand for forest statistics grows, the need to control cost has led to a consideration of alternatives to the classical methods of ground inventory. With advances in statistical theory, aerial photography has become a useful classification device in simple and multistage stratified sampling. The successful development of stand volume tables from aerial photos depends on the strength of relationships between stand volume and tree characteristics, such as crown cover and stand height, measured or estimated from aerial photographs.

Aerial photo stand volume tables have been developed for a variety of timber types and ecological conditions throughout the United States. In the West, Pope[1] and Moessner[2] have published aerial photo stand volume tables for even-aged Douglas-fir in the Pacific Northwest and for conifer stands in the Rocky Mountain States, respectively, using crown cover and stand height as the basis for computations.

First Tables for California

The preliminary tables presented in this Note are the first ones published for timber types in California. They were developed for use as a stratification tool for a two-stage sampling design now used by the Forest Survey project at the Pacific Southwest Forest and Range Experiment Station.[3] The tables were developed primarily to place photo plots (plots on photos examined stereoscopically) into rather broad volume groups rather than to estimate the volume of

[1]Pope, R.B. Constructing aerial photo volume tables. U.S. Forest Serv. Pacific NW. Forest & Range Expt. Sta. Res. Paper 49, 25 pp. 1962.

[2]Moessner, K. E. Composite aerial volume tables for conifer stands in the Mountain States. U. S. Forest Serv. Intermountain Forest & Range Expt. Sta. Res. Note INT-8, 4 pp. 1963.

[3]Grateful acknowledgment is made to P. G. Langley, of this Station, who directed the collection and processing of the data and who performed preliminary analysis of the data.

individual photo plots. However, if these tables are used for photo cruising, a random sample of the photo plots should be accurately located on the ground and measured to provide a basis for adjusting the photo-estimated gross volume to ground-measured net volume.

The data for developing the stand volume tables, i.e., stand height, crown cover, and stand gross volume, were obtained from plots measured throughout the commercially important timber types in California (table 1). Average stand height was determined from ground measurements; crown cover from aerial photo interpretation estimates. Plot volumes were computed using Forest Survey local volume tables.

Table 1.--*Number, average stand height, crown cover, and gross volume per acre of plots, by timber type, used in aerial photo volume tables for California*

Forest type	Plots	Average stand height	Average crown cover	Average volume per acre	
	Number	*Feet*	*Percent*	*Cubic feet*	*Bd. ft.*[1]
Ponderosa and Jeffrey pine	139	98	30.2	4,063	24,360
Douglas-fir	47	160	44.7	9,917	64,363
White and red fir	27	111	40.9	7,389	46,417
All white woods[2]	213	113	34.7	5,776	35,983
Old-growth redwood	42	221	47.2	29,567	172,791
Total, all species	255	--	--	--	--

[1]International 1/4-inch log rule.

[2]Composite of ponderosa and Jeffrey pine, Douglas-fir, red fir and white fir.

Species Covered in Tables

Gross cubic foot and board foot aerial photo stand-volume tables were prepared for a composite group of white wood timber types (ponderosa pine (Pinus ponderosa Laws.), Jeffrey pine (Pinus jeffreyi Grev. & Balf.), white fir (Abies concolor (Gord. & Glend.) Lindl.), California red fir (Abies magnifica A. Murr.), and Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco). Separate stand volume tables were prepared for old-growth redwood (Sequoia sempervirens (D. Don) Endl.), which differs significantly from the white wood types. Tables for young-growth redwood stands have not yet been prepared because of too few plots.

Although the tables were developed using ground stand height measurements, in actual use stand heights will be determined from aerial photo measurements. Because of the apparent variation between interpreters and interpreter's bias, the substitution of photo stand height for ground height is often accompanied by the use of individual adjustment factors to minimize interpreter's error. Whenever possible

Table 2.--*Aerial photo stand volume table*[1] *(gross volume cubic feet per acre) for ponderosa and Jeffrey pine, white and red fir, and Douglas-fir, in California (Basis: 213 plots)*

Stand height[2] (feet)	- - - Crown cover (percent)[3] - - -									
	5	15	25	35	45	55	65	75	85	95
	- - - Hundred cubic feet per acre[4] - - -									
40	1	4	6	8	11	13	15	17	19	21
50	2	6	10	13	16	20	23	26	29	32
60	3	9	14	19	23	28	32	36	40	44
70	5	12	19	25	31	36	42	47	52	57
80	6	16	24	32	39	46	53	59	65	72
90	8	20	30	39	48	56	64	72	79	87
100	10	24	36	47	57	67	76	85	94	103
110	12	29	43	55	67	78	89	99	109	119
120	15	34	50	64	77	90	102	114	125	136
130	17	39	57	73	88	102	116	129	142	154
140	20	44	64	82	99	115	130	144	158	172
150	22	50	72	92	111	128	144	160	175	190
160	25	56	80	102	122	141	159	176	193	209
170	28	62	89	112	134	155	174	192	210	227
180	32	68	97	123	146	168	189	209	228	247
190	35	74	106	134	159	182	205	226	246	266
200	38	81	115	144	171	197	220	243	264	285
210	42	88	124	156	184	211	236	260	283	305
220	46	95	133	167	197	225	252	277	301	325

[1]Gross volume in trees 5.0 inches d.b.h. and larger to top limit 4.0 inches d.i.b.
[2]Average height of dominant stand measured in the field.
[3]Includes all trees in major canopy.
[4]Block indicates the approximate extent of the data. Equation for table:

$$V_c = e^{-1.11864}(e^{-.14926 \log_e H \log_e HC})(H^2C)^{1.47240}$$

in which V_c = volume, cubic feet per acre; H = stand height in feet; C = proportion of crown coverage.

Table 3. --*Aerial photo stand volume table*[1] *(gross volume International board foot per acre) for ponderosa and Jeffrey pine, white and red fir, and Douglas-fir in California (Basis: 213 plots)*

Stand height[2] (feet)	Crown cover (percent)[3]									
	5	15	25	35	45	55	65	75	85	95
	M board feet per acre[4]									
40		1	2	3	3	4	4	5	5	6
50		2	4	5	6	7	8	9	9	10
60	1	4	6	8	10	11	12	13	14	15
70	2	6	9	12	14	16	18	19	20	21
80	3	8	13	17	20	22	25	26	27	28
90	4	11	17	22	26	29	32	34	35	36
100	5	14	22	28	33	37	40	42	44	44
110	7	18	27	35	41	45	49	51	52	53
120	8	22	33	42	49	54	58	60	62	62
130	9	26	39	49	57	62	67	69	71	71
140	11	30	44	56	65	71	76	79	80	80
150	12	33	50	63	73	80	85	88	89	90
160	13	37	55	69	80	88	93	96	98	98
170	15	40	60	76	87	96	101	105	107	107
180	16	43	64	81	94	103	109	113	115	115
190	17	45	68	86	99	109	116	120	123	123
200	17	47	71	90	104	115	122	127	130	131
210	18	49	74	93	108	120	128	134	137	138
220	18	50	75	96	112	124	133	139	143	145

[1]Gross volume in trees 11.0 inches d.b.h. and larger to average utilized top.
[2]Average height of dominant stand measured in the field.
[3]Includes all trees in major canopy.
[4]Block indicates the approximate extent of the data. Equation for table:

$$V_I = e^{-2.01192}\left(e^{H\left[-.00003H + C(.00004H - .01327)\right]}\right)(H^3C)^{1.00961}$$

in which V_I = International board foot volume per acre; H = stand height in feet; C = proportion of crown coverage.

Table 4.--*Aerial photo stand volume table*[1] *(gross volume Scribner board foot per acre) for ponderosa and Jeffrey pine, white and red fir, and Douglas-fir in California (Basis: 213 plots)*

Stand height[2] (feet)	- - - Crown cover (percent)[3] - - -									
	5	15	25	35	45	55	65	75	85	95
	- - - M board feet per acre[4] - - -									
40		1	2	2	3	3	4	4	5	5
50		2	3	4	5	6	7	8	8	9
60	1	4	6	7	9	10	11	12	13	14
70	2	5	9	11	13	15	17	18	19	20
80	3	8	12	16	19	21	23	25	26	27
90	4	10	16	21	25	28	30	32	34	34
100	5	14	21	27	32	36	39	41	42	43
110	6	17	26	34	40	44	48	50	52	52
120	7	21	32	41	48	53	57	60	61	62
130	9	25	38	48	56	63	67	70	72	72
140	10	29	44	56	65	72	77	80	82	83
150	12	33	50	64	74	82	88	91	94	94
160	13	36	56	71	83	92	98	102	105	106
170	14	40	61	78	91	101	109	114	117	118
180	15	43	66	85	100	111	119	125	129	130
190	16	46	71	91	107	120	129	136	141	143
200	17	48	75	97	114	128	139	147	153	157
210	17	50	78	102	121	137	149	158	166	170
220	18	51	81	106	127	144	158	170	178	185

[1]Gross volume in trees 11.0 inches d.b.h. and larger to average utilized top.
[2]Average height of dominant stand measured in the field.
[3]Includes all trees in major crown canopy.
[4]Block indicates the approximate extent of the data. Equation for table:

$$V_s = e^{-2.37777}\left(e^{H\left[-.00003H + C(-.01460 + .00005H)\right]}\right)(H^3C)^{1.03597}$$

in which V_s = Scribner board foot volume per acre; H = stand height in feet; C = proportion of crown coverage.

Table 5.--*Aerial photo stand volume table*[1] *for old-growth redwood in California (Basis: 42 pl*

Stand height[2] (feet)	- - - Crown cover (percent)[3] - - -									
	5	15	25	35	45	55	65	75	85	95
	- - - Hundred cubic feet per acre[4] - -									
60	13	26	36	45	53	60	67	73	79	85
70	16	32	44	55	64	73	81	89	97	104
80	19	38	52	64	76	87	96	106	115	123
90	22	44	61	75	89	101	112	123	133	143
100	25	50	70	86	101	115	128	141	153	164
110	28	57	79	98	115	130	145	159	172	185
120	31	63	88	109	128	146	162	178	193	207
130	35	70	97	121	142	162	180	197	214	230
140	38	77	107	133	156	178	198	217	235	252
150	42	84	117	145	171	194	216	237	257	276
160	45	92	127	158	185	211	235	257	279	300
170	49	99	137	171	200	228	254	278	302	324
180	53	107	148	184	216	245	273	299	325	349
190	56	114	159	197	231	263	293	321	348	374
200	60	122	169	210	247	281	313	343	372	399
210	64	130	180	224	263	299	333	365	396	425
220	68	138	191	238	279	318	353	387	420	451
230	72	146	203	252	296	336	374	410	445	477
240	76	154	214	266	312	355	395	433	470	504
250	80	163	226	280	329	374	417	457	495	531
260	84	171	237	294	346	393	438	480	520	559
270	87	179	249	309	363	413	460	504	546	587
280	93	188	261	324	380	433	482	528	572	615

[1]Gross volume in trees 5.0 inches d.b.h. and larger to top limit 4.0 inches d.o.b.
[2]Average height of dominant stand measured in the field.
[3]Includes all trees in major crown canopy.
[4]Block indicates the approximate extent of the data. Equation for table:

$$V_c = e^{3.82558(H^2C)^{0.64186}}$$

in which V_c = cubic foot volume per acre; H = stand height in feet; C = proportion of cro coverage.

Table 6.--*Aerial photo stand volume table*[1] *(gross volume International board foot per acre) for old-growth redwood in California (Basis: 42 plots)*

Stand height[2] (feet)	- - - Crown cover (percent)[3] - - -									
	5	15	25	35	45	55	65	75	85	95
	- - - M board feet per acre[4] - - -									
60	6	13	19	24	28	32	36	40	43	47
70	8	16	23	29	35	40	44	49	53	57
80	9	20	28	35	41	47	53	59	64	69
90	11	23	33	41	49	56	62	69	75	80
100	13	27	38	47	56	64	72	79	86	93
110	14	30	43	54	64	73	82	90	98	106
120	16	34	48	60	72	82	92	101	110	119
130	18	38	54	67	80	91	102	113	123	132
140	20	42	59	74	88	101	113	125	136	146
150	22	46	65	82	97	111	124	137	149	160
160	24	50	71	89	106	121	135	149	162	175
170	26	55	77	97	115	131	147	162	176	190
180	28	59	83	105	124	142	159	175	190	205
190	30	63	90	113	133	153	171	188	205	221
200	32	68	96	121	143	164	183	202	220	237
210	35	73	103	129	153	175	196	215	234	253
220	37	77	109	137	163	186	208	229	250	269
230	39	82	116	146	173	198	221	244	265	286
240	41	87	123	154	183	209	234	258	281	303
250	44	92	130	163	193	221	248	273	297	320
260	46	97	137	172	204	233	261	288	313	337
270	49	102	144	181	214	245	275	303	329	355
280	51	107	151	190	225	258	289	318	346	373

[1]Gross volume in trees 11.0 inches d.b.h. and larger to average utilized top.
[2]Average height of dominant stand measured in the field.
[3]Includes all trees in major crown canopy.
[4]Block indicates the approximate extent of the data. Equation for table:

$$V_I = e^{5.25349}(H^2C)^{0.67526}$$

in which V_I = International board foot volume per acre; H = stand height in feet; C = proportion of crown coverage.

Table 7.--*Aerial photo stand volume table*[1] *(gross volume Scribner board foot per acre) for old-growth redwood in California (Basis: 42 plots)*

Stand height[2] (feet)	- - - Crown cover (percent)[3] - - -									
	5	15	25	35	45	55	65	75	85	95
	- - - M board feet per acre[4] - - -									
60	6	13	18	22	27	30	34	38	41	44
70	7	15	22	28	33	38	42	46	51	55
80	9	19	26	33	39	45	51	56	61	66
90	10	22	31	39	46	53	59	65	71	77
100	12	25	36	45	53	61	69	76	82	89
110	14	29	41	51	61	70	78	86	94	101
120	15	32	46	58	68	78	88	97	106	114
130	17	36	51	64	76	88	98	108	118	127
140	19	40	57	71	84	97	109	120	130	141
150	21	44	62	78	93	106	119	131	143	155
160	23	48	68	85	101	116	130	144	156	169
170	25	52	74	93	110	126	141	156	170	183
180	27	56	80	100	119	136	153	169	184	198
190	29	61	86	108	128	147	165	182	198	213
200	31	65	92	116	137	158	177	195	212	229
210	33	69	98	124	147	168	189	208	227	245
220	35	74	105	132	156	179	201	222	242	261
230	37	79	111	140	166	191	214	236	257	277
240	39	83	118	148	176	202	226	250	272	293
250	42	88	125	157	186	214	239	264	288	310
260	44	93	132	166	197	225	253	279	303	327
270	46	98	139	174	207	237	266	293	319	345
280	49	103	146	183	217	249	280	308	336	362

[1]Gross volume in trees 11.0 inches d.b.h. and larger to average utilized top.
[2]Average height of dominant stand measured in the field.
[3]Includes all trees in major crown canopy.
[4]Block indicates the approximate extent of the data. Equation for table:

$$V_s = e^{5.14545(H^2C)^{0.68230}}$$

in which V_s = Scribner board foot volume per acre; H = stand height in feet; C = proportion of crown coverage.

these tables should be checked against the stands to which they are applied by selecting a sample of plots on which the necessary ground plot measurements are available or can be readily obtained.

Considerable differences may be found between ground-measured net volume of individual plots and the estimated gross volume obtained from the photo stand volume tables. These differences are associated with variability within and between timber types, amount of cull in the stand, variation in photo quality, and errors in photo interpretation.

Development of Equations

The aerial photo stand volume equations were developed on a computer, using a stepwise multiple regression program as a least squares fitting procedure. A general polynomial equation using powers, logarithms, and combinations of stand height and crown cover was fitted to the data. The equations for gross cubic foot, International board foot, and Scribner board foot volume per acre represent a compromise between goodness of fit and simplicity of form.

Because these tables are preliminary, they will be revised as additional information is collected. In the interim, the tables should prove useful in two-stage stratified sampling designs.

The Author—
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